LA-UR-19-22040
Approved for public release; distribution is unlimited.

Title: Principles of Radiation Protection

Author(s): Mcalpin, Jerry D.

Intended for: Radiological Packaging and Transportation Security Training in China

Issued: 2019-03-07

ORS
Office of Radiological Security
Protect · Remove · Reduce

Principles of Radiation Protection

Jerry McAlpin

April 2019

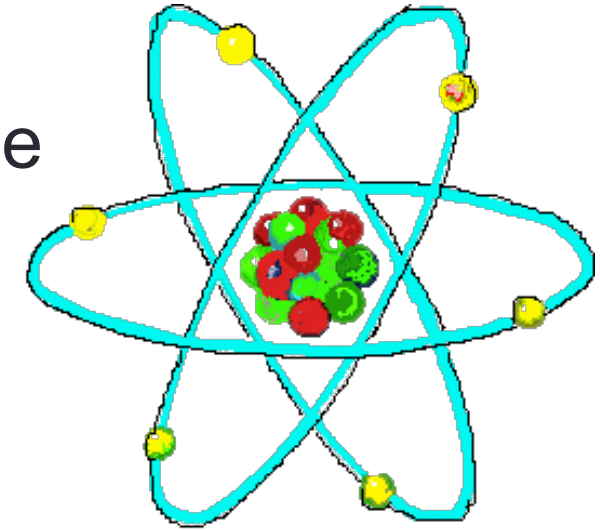
OFF-SITE SOURCE RECOVERY PROGRAM
NATIONAL SECURITY THROUGH SOURCE REMOVAL

National Nuclear Security Administration

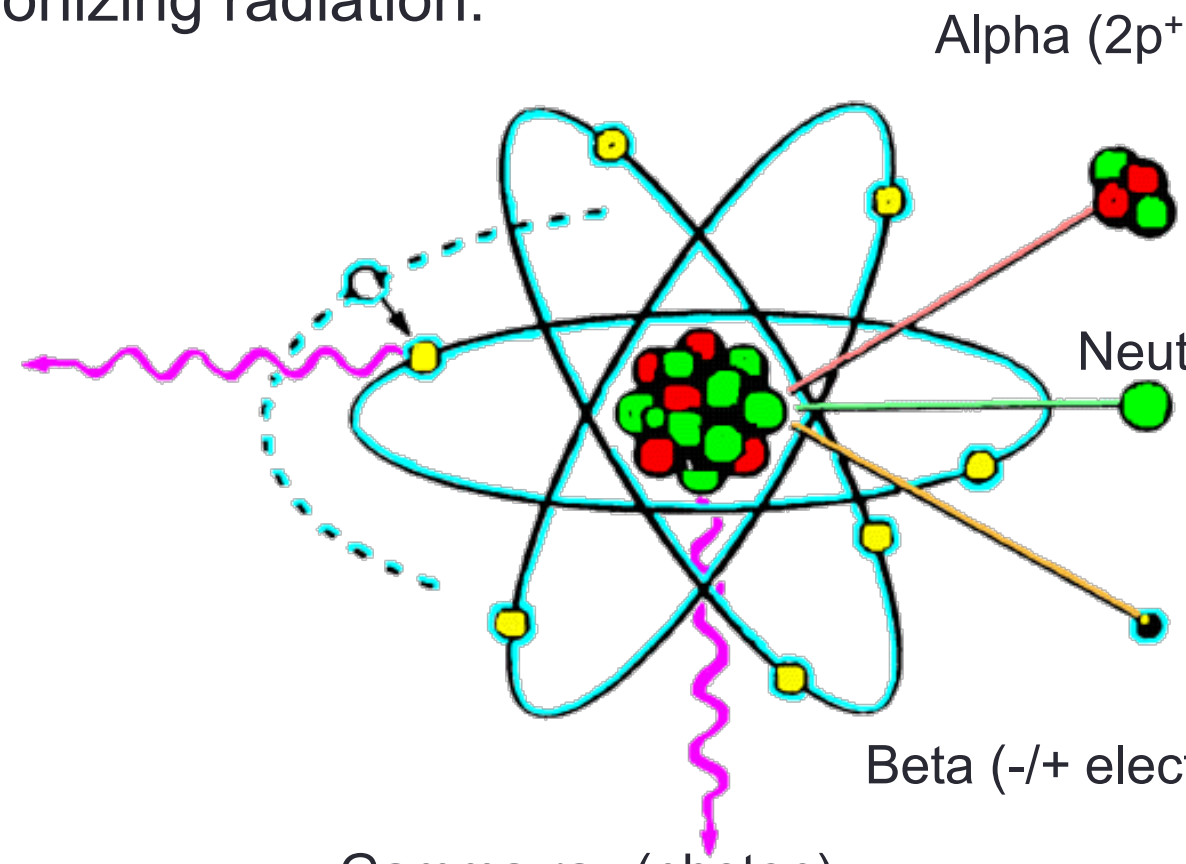
Global Material Security

Atomic Structure

- The basic unit of matter is the atom
- The three basic parts of the atom are protons, neutrons, and electrons
- The protons and neutrons comprise the nucleus or center of the atom
- Electrons orbit around the nucleus

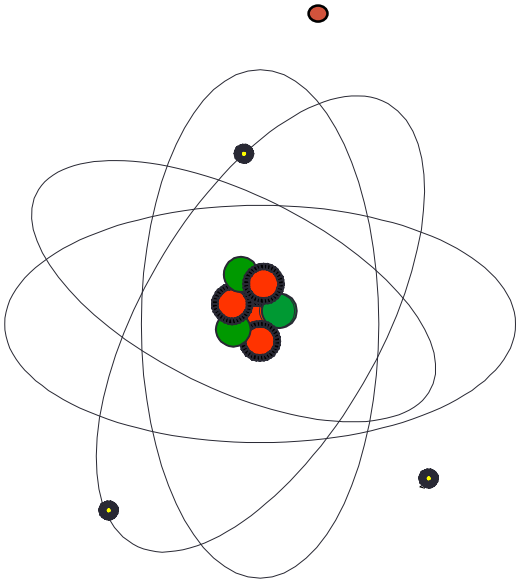


- Five types of ionizing radiation:



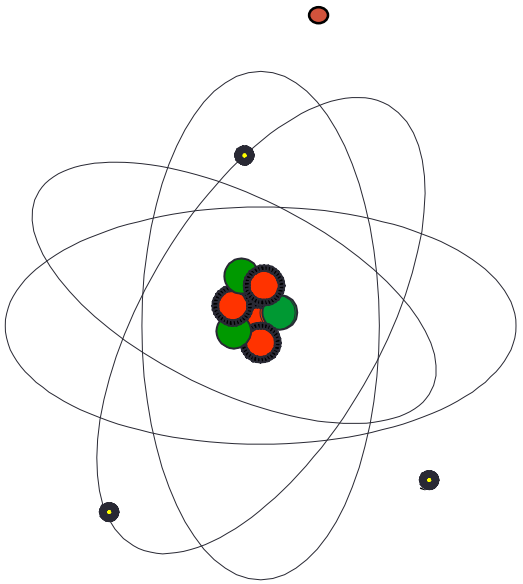
Alpha particle

- Alpha particle – a positively charged particle, physically identical to a helium nucleus
  - Physical characteristics
    - Range
    - Deposits a large amount of energy in a short distance
    - Range in air is one to two inches (2-5cm)
  - Shielding
    - A few inches of air
    - A sheet of paper will stop it
  - Biological hazard
    - Internal only, NOT external



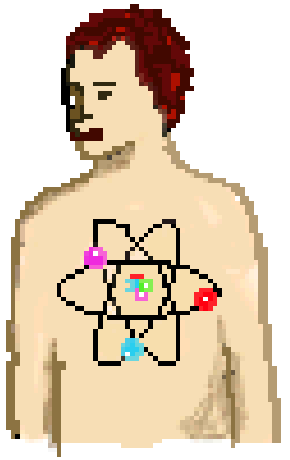
Beta Particle

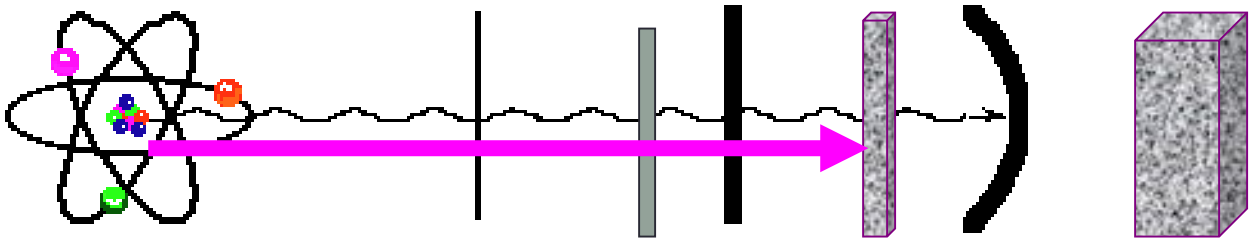
- Beta particle – a high speed electron that was emitted from an atom
  - Physical characteristics
    - Range
      - Range in air is about 3 m (10 feet) per MeV of energy
    - Shielding
      - Plastics (low Z material)
      - Layered shield with low Z material on the inside and high Z material on the outside
    - Biological hazard
      - Skin, eyes, and internal



Gamma Properties

- Gamma and X-ray physical characteristics
  - Range
    - Range in air is several hundred feet (100m)
  - Shielding
    - Lead
    - Concrete
    - Steel or any dense substance
  - Biological hazard
    - Whole body hazard





Radioactivity

Radioactivity is measured by the number of disintegrations occurring in a certain period of time

3.7 x 10^{10} disintegrations per second (dps) = 1 gram of Ra-226 = 1 Curie (Ci) = 37,000 MBq

Becquerel (Bq) = 1 dps

1 TBq = 27 Ci

37 GBq = 1 Ci

37,000 MBq = 1 Ci

English Units:

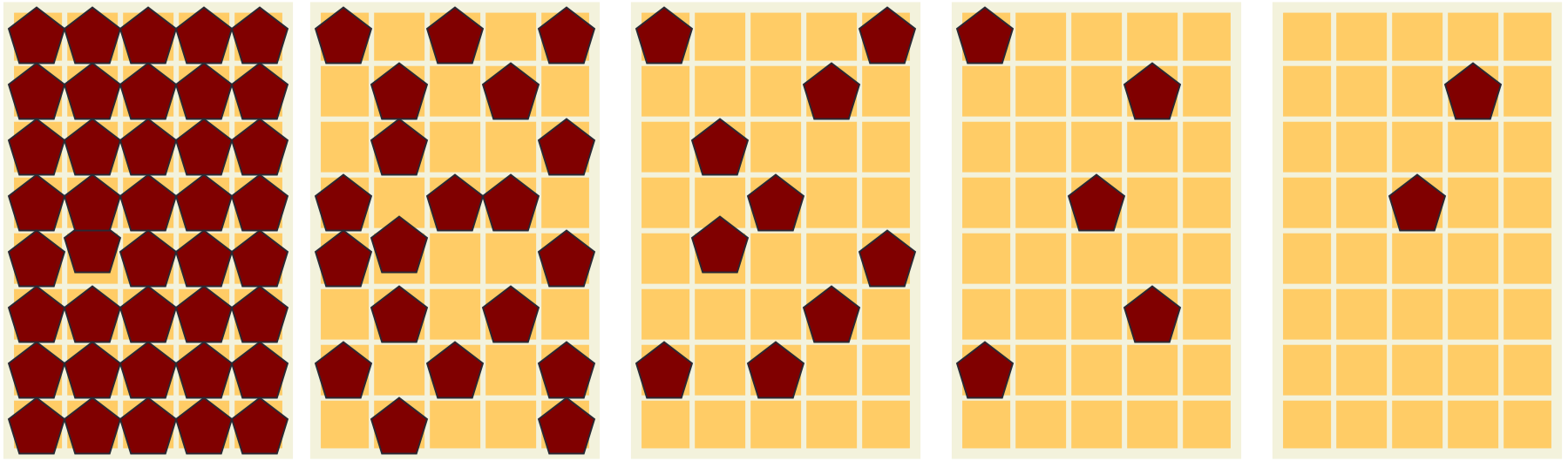
1 Ci = 1000 mCi

1 mCi = 1000 microCi

ORS
Office of Radiological Security
Protect · Remove · Reduce

Radioactivity

- Radioactive half-life is the time it takes for half of the radioactive atoms to decay



National Nuclear Security Administration
Global Material Security

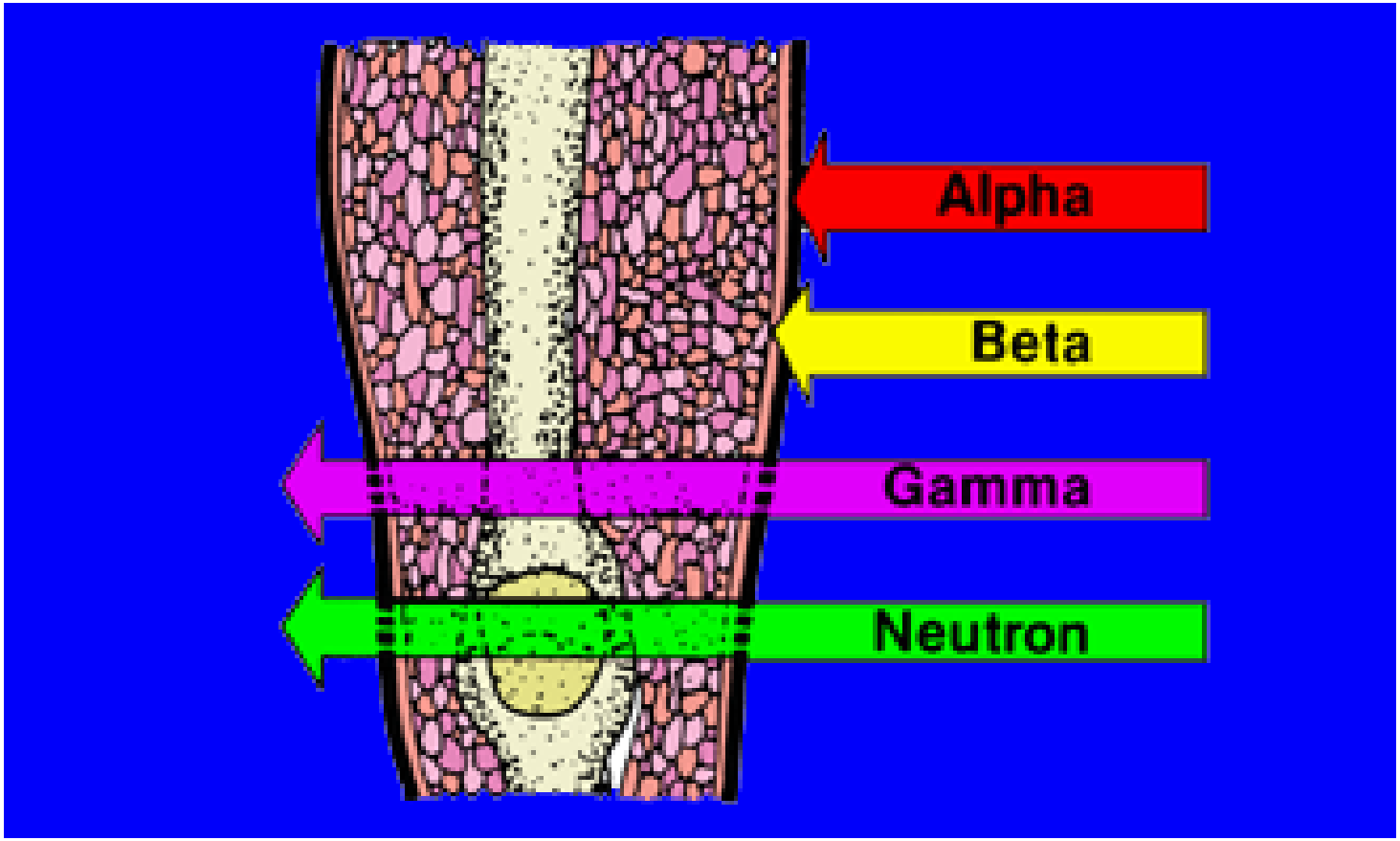
Radioactivity (cont.)

Radionuclide	Half-life
Uranium-238	4,500,000,000 years
Plutonium-239	24,000 years
Radium-226	1,600 years
Americium-241	432 years
Cesium-137	30.2 years
Strontium-90	28.8 years
Cobalt-60	5.3 years
Iridium-192	75 days

In general, the less stable the radionuclide the shorter the half-life

ORS
Office of Radiological Security
Protect · Remove · Reduce

Comparison of Penetrating Power of Ionizing Radiations



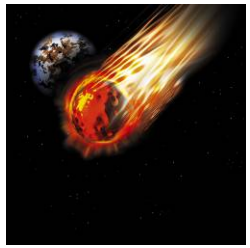
National Nuclear Security Administration
Global Material Security

THE ELECTROMAGNETIC SPECTRUM

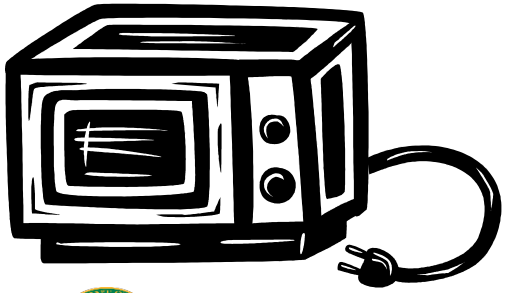
LOWER FREQUENCY ← → HIGHER FREQUENCY

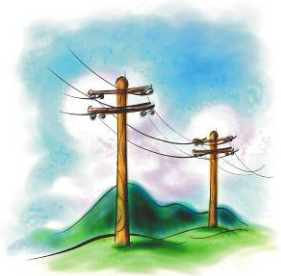
LONGER WAVELENGTH ← → SHORTER WAVELENGTH

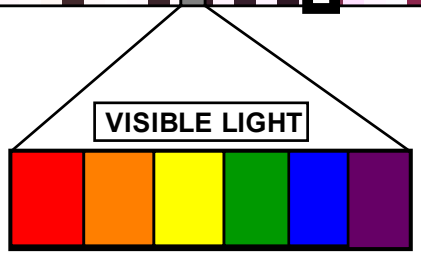
LESS ENERGY ← → MORE ENERGY



NON-IONIZING RADIATION				IONIZING RADIATION	
RADIOFREQUENCY	MICROWAVES	INFRARED	UV	X-RAYS GAMMA	COSMIC RADIATION

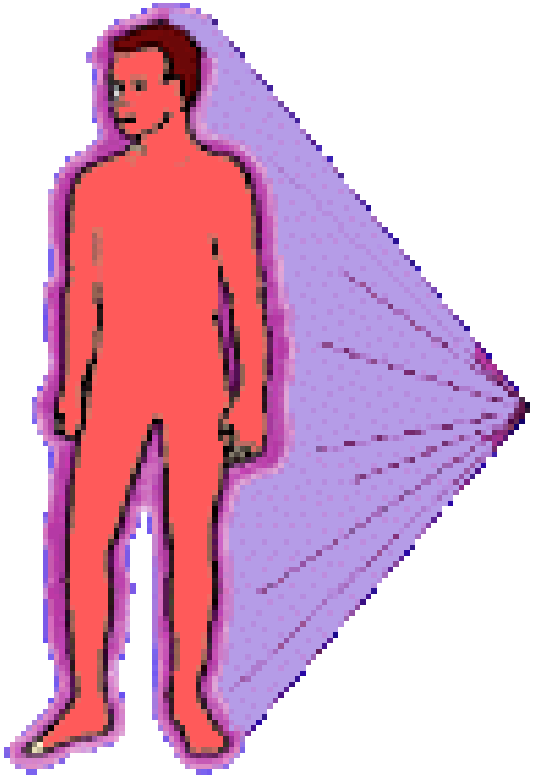






Sieverts

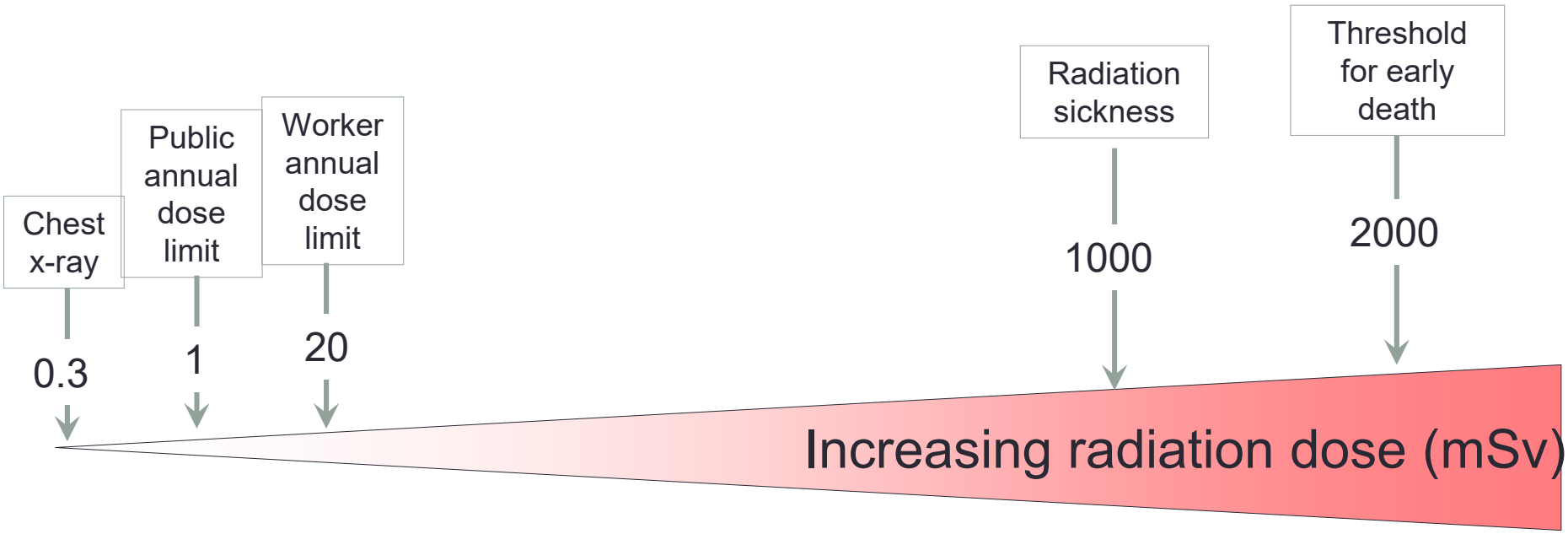
- Unit for measuring dose equivalence
- Most commonly used unit
- Pertains to the human body
- Takes into account biological effects from different types of radiation
- 1 Sievert = 1000 mSv
- English units:
  - 1 Sievert (Sv) = 100 rem
  - 1 rem = 1000 mrem



ORS
Office of Radiological Security
Protect · Remove · Reduce

Comparison of Radiation Doses

1 millisievert (mSv) = 1/1000 Sievert



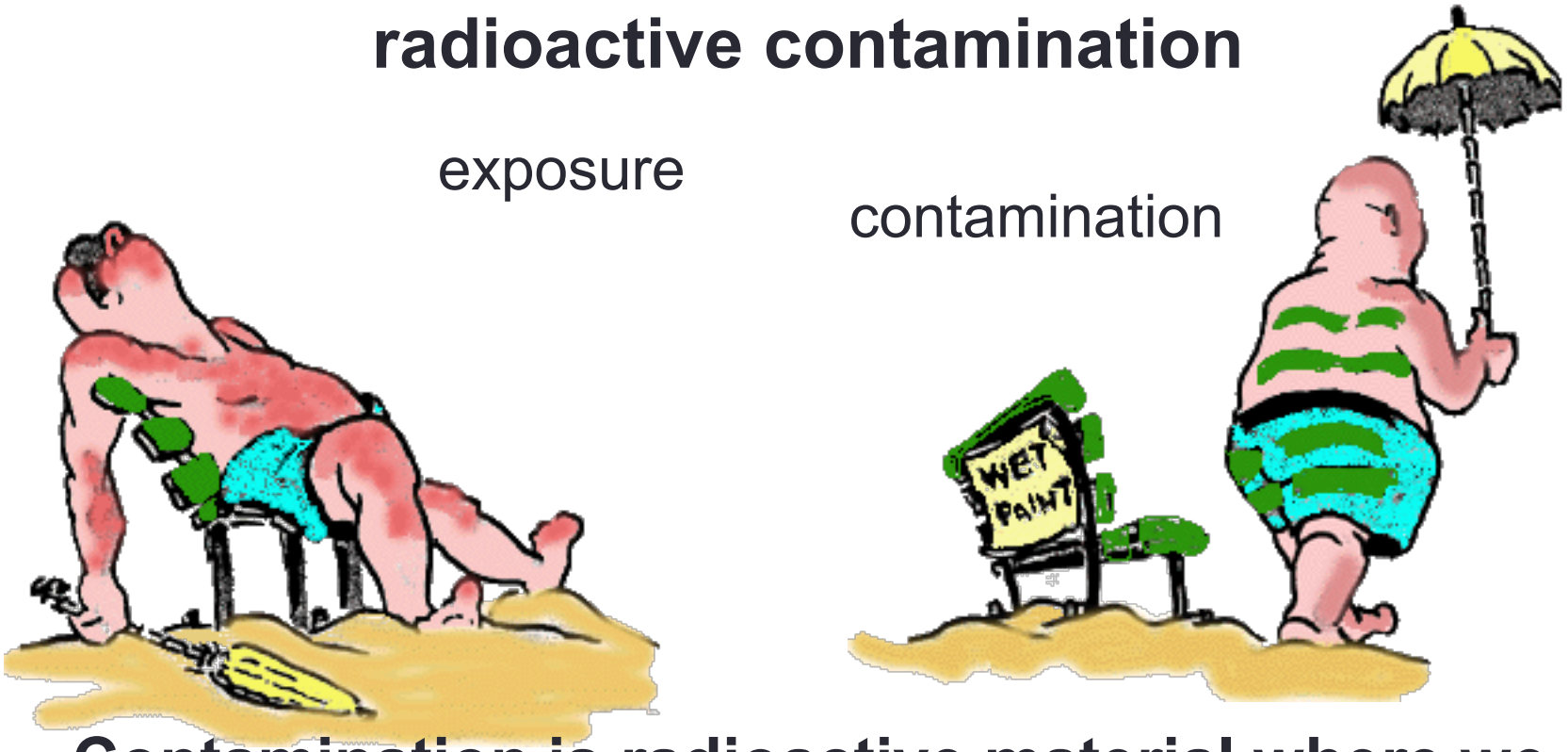
National Nuclear Security Administration
Global Material Security

Radiation vs Contamination

Exposure to radiation fields cannot result in radioactive contamination

exposure

contamination



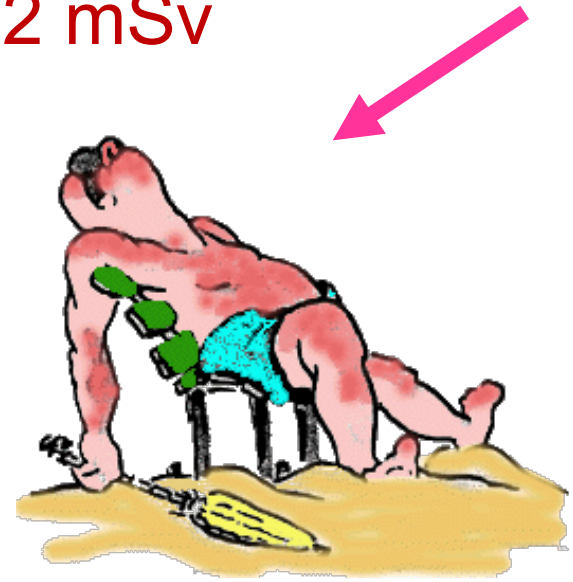
Contamination is radioactive material where we don't want it

ORS
Office of Radiological Security
Protect · Remove · Reduce

Dose vs Dose rate

- **Radiation Dose Rate** is the rate at which you receive the dose (i.e., mSv/hr or mRem/hr)
- **Radiation Dose** is the amount of radiation you receive (i.e., mSv or mRem)
- Dose Rate X Time = Dose

  1 mSv/hr X 2 hours = 2 mSv



National Nuclear Security Administration
Global Material Security

Types of Contamination

Types of Contamination

- Fixed contamination is contamination that cannot be readily removed from surfaces

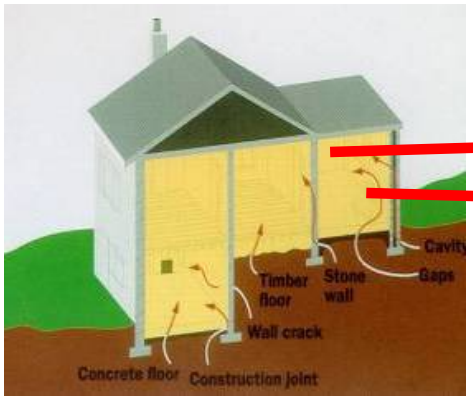
- Removable/transferable contamination is contamination that can readily be removed from surfaces

- Airborne contamination is contamination suspended in air

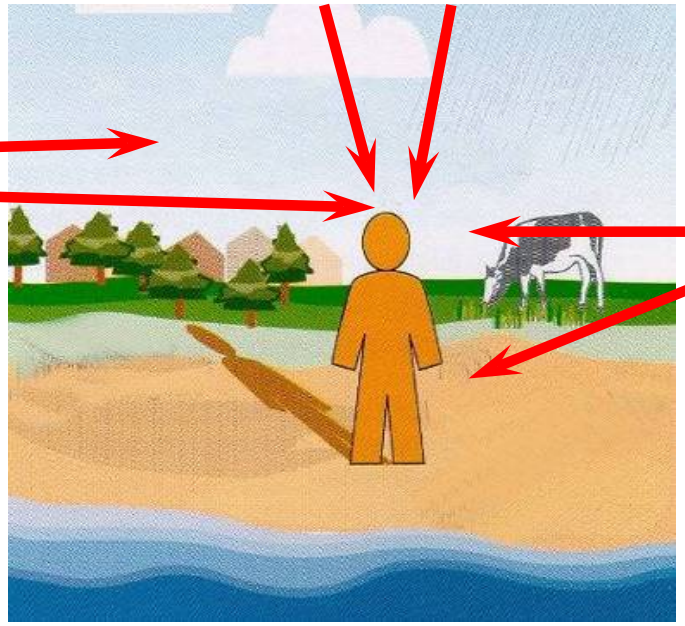
Sources of Radiation

Radiation and radioactive substances are all around us everyday

Cosmic Rays



Radon



Terrestrial gamma rays

Food & drink

ORS
Office of Radiological Security
Protect · Remove · Reduce

Biological Effects of Acute Ionizing Radiation

Dose Received	Resulting Effects
Less than 0.10 Sv	No detectable effects
0.10 – 0.25 Sv	Minor blood changes
1.0 Sv	Temporary sterilization in males
3.0 Sv	GI effects – nausea, vomiting, lining damage
3.0 – 5.0 Sv	Lethal Dose 50% of the population in 30 days (LD50/30)
10.0 Sv	Lethal
50.0 Sv	Central Nervous System – Brain damage, CNS failure

National Nuclear Security Administration
Global Material Security

We live in a radioactive world and always have; in fact, the average person in USA in early 1980s received approximately 3.6 mSv /year from background exposure from the following natural and man-made sources (National Council on Radiation Protection – NCRP Report No. 93):

Radon (2.0 mSv)

Terrestrial radiation (.28 mSv)

Cosmic radiation (.28 mSv)

Human body (.39 mSv)

Medical diagnostics (.39 mSv)

Consumer products (.10 mSv)

Medical therapy (.13 mSv)

Other sources (.03 mSv)

Due to an increase in medical procedures involving radiation (e.g., CT scans), the average person in the US receives (in 2006) approximately 6.2 mSv /year from background exposure from the following natural and manmade sources (NCRP Report No. 160):

Natural background (3.11 mSv)

Medical diagnostics and therapy (3.0 mSv)

Consumer products (.13 mSv)

Industrial, security (.003 mSv) educational, research

Occupational (.005 mSv)

Acute Dose

An Acute Dose (large exposure in a short time)

Dose Received	Resulting Effects
Less than 0.10 Sv	No detectable effects
0.10-0.25 Sv	Minor blood changes
1.0 Sv	Temporary sterilization in males
3.0 Sv	GI effects – nauseous, lining damage
3.0-5.0 Sv	Lethal Dose - 50% population in 30 days (LD 50/30)
10.0 Sv	Lethal
50.0 Sv	Central nervous system – brain damage, CNS failure

ORS
Office of Radiological Security
Protect · Remove · Reduce

Estimated days of life expectancy lost

Health risks associated with these daily activities

Activity	Average Estimate Days Lost
Unmarried male (risky behavior)	3500
Cigarette smoking (cancer)	2250
Unmarried female (risky behavior)	1600
Coal mining (dangerous job)	1100
25% overweight (bad health risk)	777
Construction worker (dangerous job)	227
Driving a motor vehicle (accident)	207
1.0 mSv/year for 70 years	10

National Nuclear Security Administration
Global Material Security

Radiation Dose Limits

Radiation Workers

- Whole body dose limit (not counting extremities) during routine conditions is 20 mSv/year
- When averaged over 5 years, the maximum in 1 year must be
  < 50 mSv

Public

- Dose limit is 1 mSv/year

ALARA

The philosophy of keeping radiation doses *As Low as Reasonably Achievable*

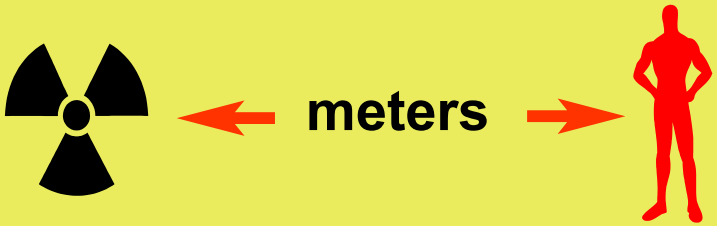
- Minimizing personal exposure by observing good radiation safety practices
- Wearing your dosimetry, using radiation detection equipment when entering areas with radioactive sources, and tracking personal exposure
- Awareness of radioactive sources in your work environment, minimizing time near the source, maximizing distance from the source, and using shielding between you and the source
- Exercising stop work authority as necessary

ORS
Office of Radiological Security
Protect · Remove · Reduce

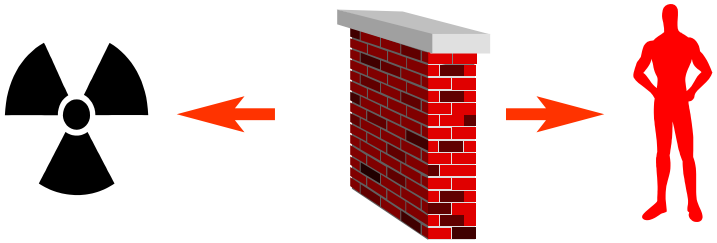
How to Decrease Radiation Dose

Time

Distance



Shielding

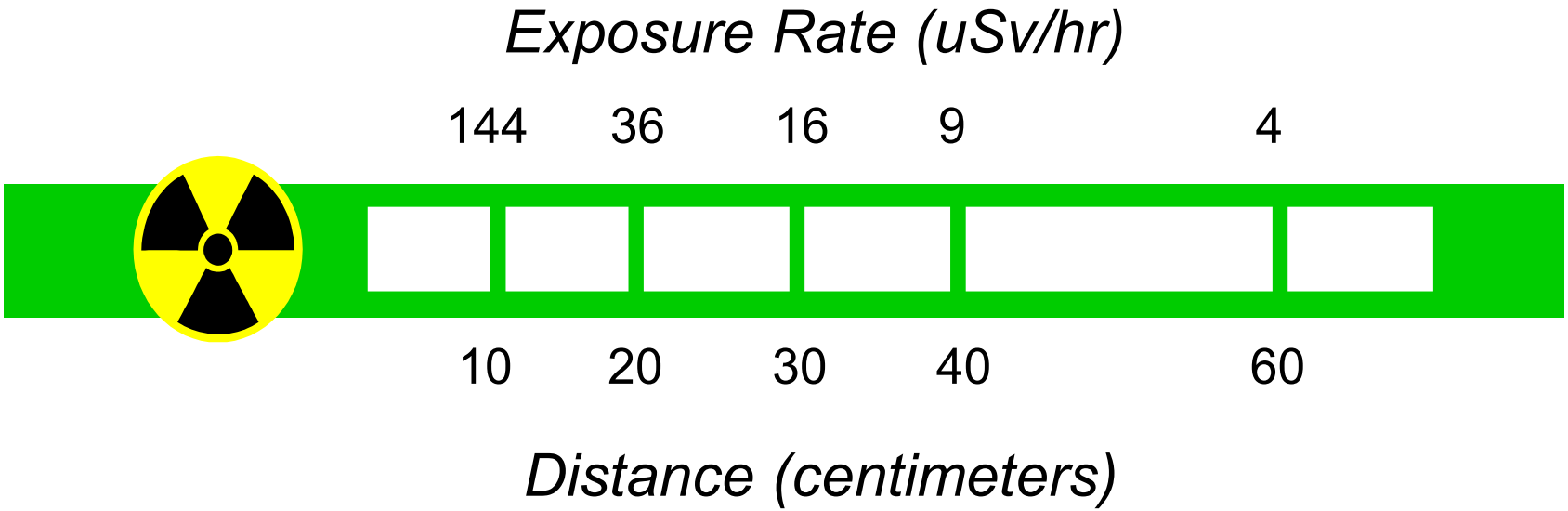


National Nuclear Security Administration
Global Material Security

Distance

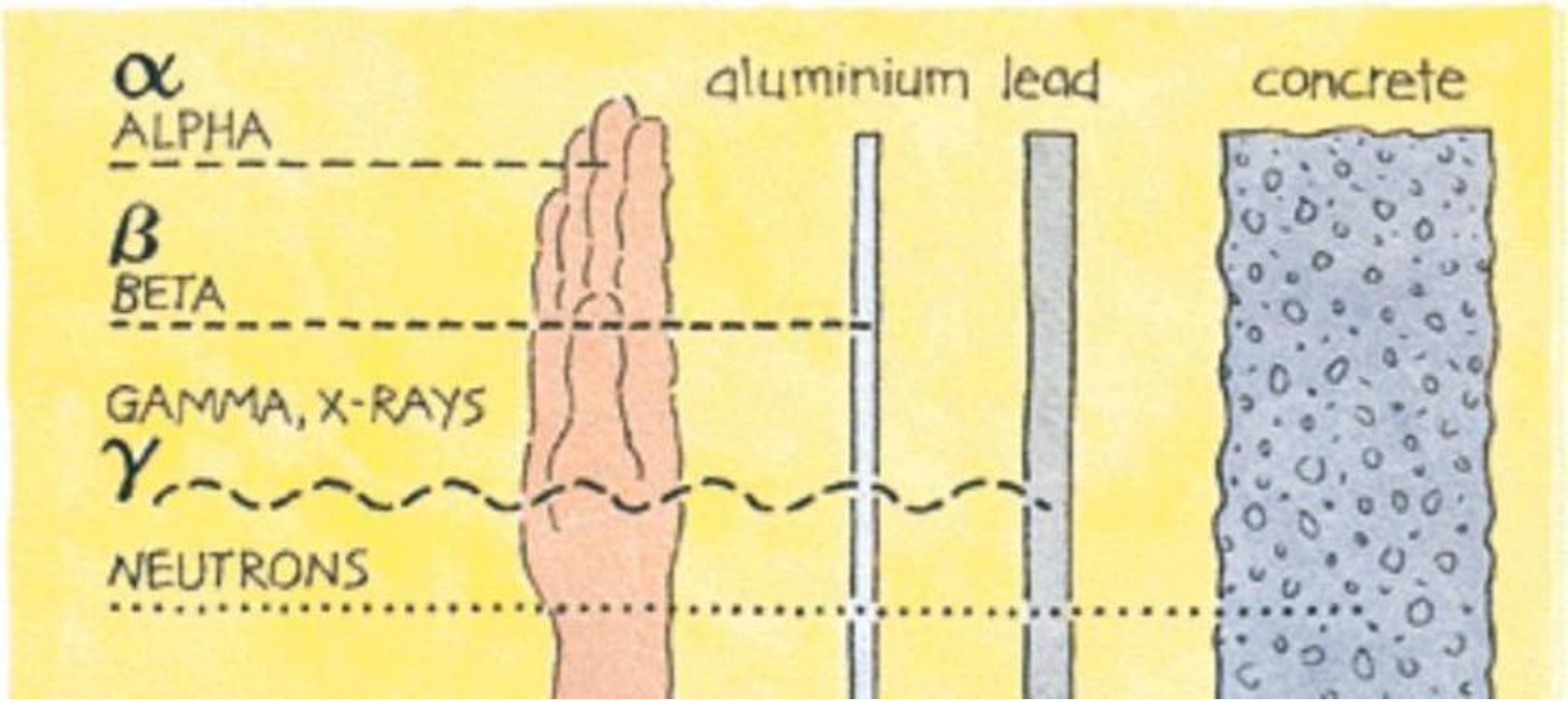
Inverse Square Law

The great benefit of distance from the source



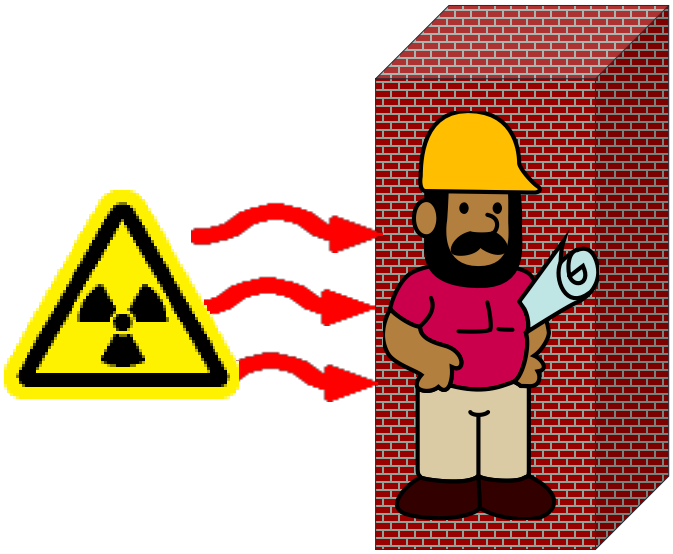
Shielding

Penetration of Radiation



Control of External Exposure

Spend less time
in the radiation
(½ time = ½ dose)



Move away from the radiation

(Double distance = ¼ dose)

Use
shielding

Dosimetry

- Source roundup team members need to wear dosimetry to record radiation exposures received while performing source recovery operations
- Some dosimetry to consider are the following:
  - Whole body dosimeters for recording dose of record
  - Alarming secondary dosimeters that provide real time indication of dose
  - Extremity dosimeters

ORS
Office of Radiological Security
Protect · Remove · Reduce

Summary for Individuals

- Wear proper dosimetry
  - Whole body dosimeter
  - Alarming secondary dosimeter
  - Extremity dosimeter
- Wear proper protective equipment (as needed)
  - Gloves
  - Coveralls
  - Boots (or easily decontaminated footwear)
  - Carry appropriate radiation/contamination detectors – or be with someone who does
  - Use long handle tools when handling radioactive sources
  - Know the radiation doses and dose rates that require action

National Nuclear Security Administration
Global Material Security